Hyperparameters

```
IMAGE_SIZE = 64
EPOCHS = 50
BATCH_SIZE = 64
DATASET_FOLDER = 'simpsons_input/'
LR_D = 0.00004
LR_G = 0.0004
BETA1 = 0.5
WEIGHT_INIT_STDDEV = 0.02
EPSILON = 0.00005
```

Imports

```
from datetime import datetime
import os
from glob import glob
from IPython import display
import imageio
import matplotlib.pyplot as plt
%matplotlib inline
import numpy as np
import PIL
from PIL import Image
import pytz
tz_NY = pytz.timezone('America/New_York')
import random
from scipy import ndarray
import skimage as sk
from skimage import io
from skimage import util
from skimage import transform
import tensorflow as tf
from tensorflow.keras import layers
import time
```

Image presentation functions

```
def generate_and_save_images(model, epoch, test_input, save_image=True):
  # Notice `training` is set to False.
  # This is so all layers run in inference mode (batchnorm).
  predictions = model(test_input, training=False)

```

```
  fig = plt.figure(figsize=(4,4))

  for i in range(predictions.shape[0]):
      plt.subplot(4, 4, i+1)
      generated_image2 = predictions[i].numpy() * 127.5 + 127.5
      plt.imshow(generated_image2.astype('uint8'))

      plt.axis('off')

  if save_image:
    plt.savefig('image_at_epoch_{:04d}.png'.format(epoch))
  plt.show()
```

```
def show_samples(sample_images):

    print("len(sample_images): ", len(sample_images))
    print("len(sample_images): ", sample_images[0].shape)

    figure, axes = plt.subplots(1, len(sample_images), figsize = (50, 50))

    print("figure: ", figure)
    print("axes: ", axes)

    for index, axis in enumerate(axes):
        axis.axis('off')
        image_array = sample_images[index]
        axis.imshow(image_array)

    plt.show()
    plt.close()
```

```
def show_image_custom(input_image):
    fig = plt.figure(figsize=(4,4))

    plt.imshow(input_image)

    plt.axis('off')

    plt.show()
```

```
def show_samples2(sample_images):
    figure, axes = plt.subplots(1, len(sample_images), figsize = (50, 50))

    for index, axis in enumerate(axes):
        axis.axis('off')
        image_array = sample_images[index]
        image_array = image_array.numpy() * 127.5 + 127.5
        axis.imshow(image_array.astype(np.uint8))

    plt.show()
```

```
    plt.close()
```

Data Preparation

```
from google.colab import drive
drive.mount('/content/drive')
ZIP_FILE = '/content/drive/My\ Drive/UoT/Assignment4/simpsons-faces.zip'
!cp $ZIP_FILE .
!unzip -q -o 'simpsons-faces.zip'
```

```
Go to this URL in a browser: https://accounts.google.com/o/oauth2/auth?client_id=947318

Enter your authorization code:
··········
Mounted at /content/drive
```

```
from shutil import copytree, ignore_patterns

# remove the images that don't have characters
def prepareDataset(src, dst):
    if not os.path.exists(src):
        os.makedirs(src)
    copytree(src, dst, ignore=ignore_patterns("9746.*","9731.*","9717.*","9684.*","9637.
"9250.*","9251.*","9252.*","9043.*","8593.*","8584.*","8052.*","8051.*","8008.*","7957.*
"7958.*","7761.*","7762.*","9510.*","9307.*","4848.*","4791.*","4785.*","4465.*","2709.*
"7724.*","7715.*","7309.*","7064.*","7011.*","6961.*","6962.*","6963.*","6960.*","6949.*
"6662.*","6496.*","6409.*","6411.*","6406.*","6407.*","6170.*","6171.*","6172.*","5617.*
"4363.*","4232.*","4086.*","4047.*","3894.*","3889.*","3493.*","3393.*","3362.*","2780.*
"2710.*","2707.*","2708.*","2711.*","2712.*","2309.*","2056.*","1943.*","1760.*","1743.*
"1702.*","1281.*","1272.*","772.*","736.*","737.*","691.*","684.*","314.*","242.*","191.

prepareDataset('./cropped', DATASET_FOLDER)
```

```
input_images = np.asarray([np.asarray(
    Image.open(file)
    .resize((IMAGE_SIZE, IMAGE_SIZE))
    ) for file in glob(DATASET_FOLDER+'*')])
print ("Input: " + str(input_images.shape))

np.random.shuffle(input_images)

sample_images = input_images[:5]
show_samples(sample_images)
```

```
Input: (9796, 64, 64, 3)
len(sample_images):  5
len(sample_images):  (64, 64, 3)
figure:  Figure(3600x3600)
axes:  [<matplotlib.axes._subplots.AxesSubplot object at 0x7f91172a9e48>
 <matplotlib.axes._subplots.AxesSubplot object at 0x7f91173270b8>
 <matplotlib.axes._subplots.AxesSubplot object at 0x7f911721b2e8>
 <matplotlib.axes._subplots.AxesSubplot object at 0x7f911724f518>
 <matplotlib.axes._subplots.AxesSubplot object at 0x7f91171c4748>]
```

```
train_images = input_images.reshape(input_images.shape[0], IMAGE_SIZE, IMAGE_SIZE, 3).as
train_images = (train_images - 127.5) / 127.5

# Batch and shuffle the data
BUFFER_SIZE = input_images.shape[0]
train_dataset = tf.data.Dataset.from_tensor_slices(train_images).shuffle(BUFFER_SIZE).ba
```

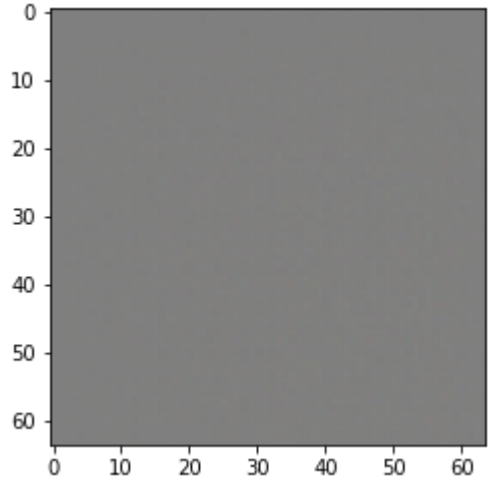
Generator

```
def make_generator_model():

    model = tf.keras.Sequential()

    # 4x4x1024
    model.add(layers.Dense(4*4*1024, input_shape=(100,)))
    model.add(layers.Reshape((4, 4, 1024)))
    model.add(layers.LeakyReLU())

    # 4x4x1024 -> 8x8x512
    model.add(layers.Conv2DTranspose(512,
                                     (5, 5),
                                     strides=(2, 2),
                                     padding='same',
                                     kernel_initializer=tf.keras.initializers.TruncatedN
                                    ))
    model.add(layers.BatchNormalization(epsilon=EPSILON))
    model.add(layers.LeakyReLU())

    # 8x8x512 -> 16x16x256
    model.add(layers.Conv2DTranspose(256,
```

```
                                    (5, 5),
                                    strides=(2, 2),
                                    padding='same',
                                    kernel_initializer=tf.keras.initializers.TruncatedN
    model.add(layers.BatchNormalization(epsilon=EPSILON))
    model.add(layers.LeakyReLU())

    # 16x16x256 -> 32x32x128
    model.add(layers.Conv2DTranspose(128,
                                    (5, 5),
                                    strides=(2, 2),
                                    padding='same',
                                    kernel_initializer=tf.keras.initializers.TruncatedN
    model.add(layers.BatchNormalization(epsilon=EPSILON))
    model.add(layers.LeakyReLU())

    # 32x32x128 -> 64x64x64
    model.add(layers.Conv2DTranspose(64,
                                    (5, 5),
                                    strides=(2, 2),
                                    padding='same',
                                    kernel_initializer=tf.keras.initializers.TruncatedN
    model.add(layers.BatchNormalization(epsilon=EPSILON))
    model.add(layers.LeakyReLU())

    # 64x64x64 -> 64x64x3
    model.add(layers.Conv2DTranspose(3,
                                    (5, 5),
                                    strides=(1, 1),
                                    padding='same',
                                    kernel_initializer=tf.keras.initializers.TruncatedN
                                    activation='tanh'))

    return model
```

```
generator = make_generator_model()

noise = tf.random.normal([1, 100])
generated_image = generator(noise, training=False)

generated_image2 = generated_image[0].numpy() * 127.5 + 127.5

plt.imshow(generated_image2.astype('uint8'))
```

```
<matplotlib.image.AxesImage at 0x7f910029cf60>
```



Discriminator

```
def make_discriminator_model():

    model = tf.keras.Sequential()
    # 64*64*3 -> 32x32x64
    model.add(layers.Conv2D(64, (5, 5), strides=(2, 2), padding='same',
                                    kernel_initializer=tf.keras.initializers.TruncatedN
    model.add(layers.BatchNormalization(epsilon=EPSILON))
    model.add(layers.LeakyReLU())

    # 32x32x64-> 16x16x128
    model.add(layers.Conv2D(128, (5, 5), strides=(2, 2), padding='same',
                                    kernel_initializer=tf.keras.initializers.TruncatedN
    model.add(layers.BatchNormalization(epsilon=EPSILON))
    model.add(layers.LeakyReLU())

    # 16x16x128 -> 8x8x256
    model.add(layers.Conv2D(256, (5, 5), strides=(2, 2), padding='same',
                                    kernel_initializer=tf.keras.initializers.TruncatedN
    model.add(layers.BatchNormalization(epsilon=EPSILON))
    model.add(layers.LeakyReLU())

    # 8x8x256 -> 8x8x512
    model.add(layers.Conv2D(512, (5, 5), strides=(1, 1), padding='same',
                                    kernel_initializer=tf.keras.initializers.TruncatedN
    model.add(layers.BatchNormalization(epsilon=EPSILON))
    model.add(layers.LeakyReLU())

    # 8x8x512 -> 4x4x1024
    model.add(layers.Conv2D(1024, (5, 5), strides=(2, 2), padding='same',
                                    kernel_initializer=tf.keras.initializers.TruncatedN
    model.add(layers.BatchNormalization(epsilon=EPSILON))
```

```
    model.add(layers.BatchNormalization(epsilon=EPSILON))
    model.add(layers.LeakyReLU())


    model.add(layers.Flatten())
    model.add(layers.Dense(1, activation='sigmoid'))

    return model
```

```
discriminator = make_discriminator_model()
decision = discriminator(generated_image)
print (decision)
```

```
tf.Tensor([[0.49988815]], shape=(1, 1), dtype=float32)
```

Define the loss and optimizers

```
# This method returns a helper function to compute cross entropy loss
cross_entropy = tf.keras.losses.BinaryCrossentropy(from_logits=True)
```

```
def discriminator_loss(real_output, fake_output):
    real_loss = cross_entropy(tf.ones_like(real_output), real_output)
    fake_loss = cross_entropy(tf.zeros_like(fake_output), fake_output)
    total_loss = real_loss + fake_loss
    return total_loss
```

```
def generator_loss(fake_output):
    return cross_entropy(tf.ones_like(fake_output), fake_output)
```

```
generator_optimizer = tf.keras.optimizers.Adam(1e-4)
discriminator_optimizer = tf.keras.optimizers.Adam(1e-4)
```

Define the training loop

```
noise_dim = 100
num_examples_to_generate = 16

# We will reuse this seed overtime (so it's easier)
# to visualize progress in the animated GIF)
seed = tf.random.normal([num_examples_to_generate, noise_dim])
```

```
def summarize_epoch(epoch, d_losses, g_losses, save_image=True):

    fig, ax = plt.subplots()
    plt.plot(d_losses, label='Discriminator', alpha=0.6)
    plt.plot(g_losses, label='Generator', alpha=0.6)
```

```
    plt.plot(g_losses, label="Generator", alpha=0.6)
    plt.title("Losses")
    plt.legend()
    if save_image:
        plt.savefig("losses_" + str(epoch) + ".png")
    plt.show()
    plt.close()
```

```
# Notice the use of `tf.function`
# This annotation causes the function to be "compiled".
@tf.function
def train_step(images):
    noise = tf.random.normal([BATCH_SIZE, noise_dim])

    with tf.GradientTape() as gen_tape, tf.GradientTape() as disc_tape:
      generated_images = generator(noise, training=True)

      real_output = discriminator(images, training=True)
      fake_output = discriminator(generated_images, training=True)

      gen_loss = generator_loss(fake_output)
      disc_loss = discriminator_loss(real_output, fake_output)

    gradients_of_generator = gen_tape.gradient(gen_loss, generator.trainable_variables)
    gradients_of_discriminator = disc_tape.gradient(disc_loss, discriminator.trainable_v

    generator_optimizer.apply_gradients(zip(gradients_of_generator, generator.trainable_
    discriminator_optimizer.apply_gradients(zip(gradients_of_discriminator, discriminato

    return gen_loss, disc_loss
```

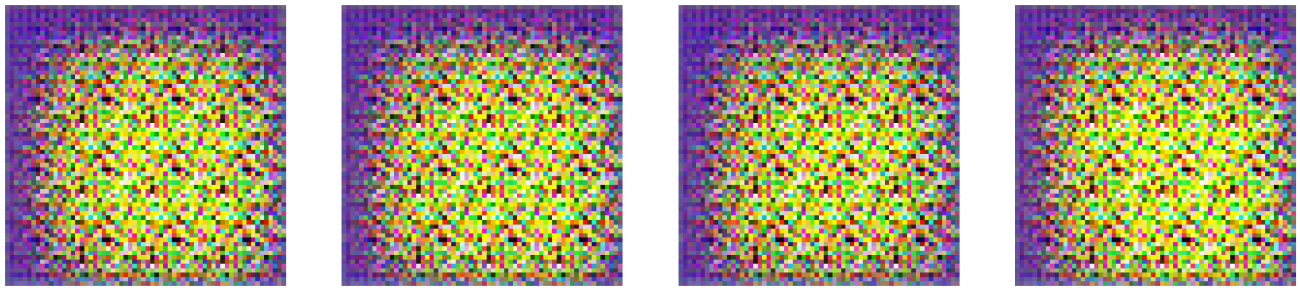
```
def train(dataset, epochs):
  print('Training started at: ', datetime.now(tz_NY))
  save_image = False
  d_losses = []
  g_losses = []
  for epoch in range(epochs):
    start = time.time()

    for image_batch in dataset:
      d_loss, g_loss = train_step(image_batch)
      d_losses.append(d_loss)
      g_losses.append(g_loss)

    # Produce images for the GIF as we go
    display.clear_output(wait=True)


    # Save the model every 15 epochs
    if (epoch + 1) % 30 == 0:
```

```
        save_image = True

      generate_and_save_images(generator,
                               epoch + 1,
                               seed,
                               save_image)
      summarize_epoch(epoch, d_losses, g_losses, save_image)
      save_image = False
      print ('Time for epoch {} is {} sec'.format(epoch + 1, time.time()-start))

    # Generate after the final epoch
    display.clear_output(wait=True)
    generate_and_save_images(generator,
                             epochs,
                             seed)
    summarize_epoch(epoch, d_losses, g_losses)


```

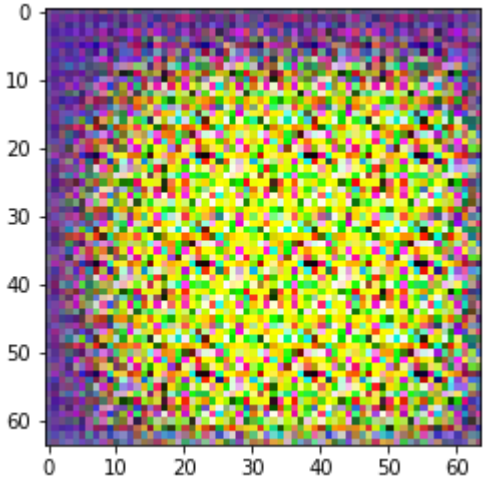
Train the model

```
train(train_dataset, EPOCHS)
```

```
noise = tf.random.normal([5, 100])
generated_image = generator(noise, training=False)
show_samples2(generated_image)
```



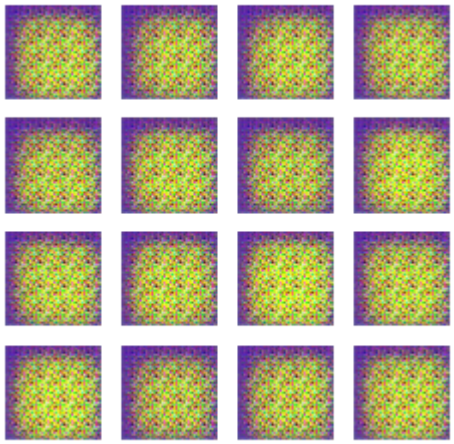
```
noise = tf.random.normal([1, 100])
generated_image = generator(noise, training=False)
generated_image2 = generated_image[0].numpy() * 127.5 + 127.5

plt.imshow(generated_image2.astype(np.uint8))
plt.show()
plt.close()
```



Create a GIF

```
# Display a single image using the epoch number
def display_image(epoch_no):
  return PIL.Image.open('image_at_epoch_{:04d}.png'.format(epoch_no))
```

```
display_image(EPOCHS)
```



Use `imageio` to create an animated gif using the images saved during training.

```
anim_file = 'dcgan.gif'

with imageio.get_writer(anim_file, mode='I') as writer:
  filenames = glob('image*.png')
  filenames = sorted(filenames)
  last = -1
  for i,filename in enumerate(filenames):
    frame = 2*(i**0.5)
    if round(frame) > round(last):
      last = frame
    else:
      continue
    image = imageio.imread(filename)
    writer.append_data(image)
  image = imageio.imread(filename)
  writer.append_data(image)

import IPython
if IPython.version_info > (6,2,0,''):
  display.Image(filename=anim_file)
```

If you're working in Colab you can download the animation with the code below:

```
try:
    from google.colab import files
except ImportError:
    pass
else:
    files.download(anim_file)
```